IMPEDANCE BLOCKING FILTER CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is a continuation-in-part application based on prior application Serial No. 09/195,522 filed on November 19,1998, and entitled "Impedance Blocking Filter Circuit."

BACKGROUND OF THE INVENTION

1. Field of the Invention:

This invention relates generally to telecommunication systems and more particularly, it relates to an impedance blocking filter circuit used in telecommunication systems for interconnecting between incoming telephone lines from a telephone company's central office (C.O.) and subscriber or customer telephone equipment such as a telephone set located at a subscriber's premises so as to unconditionally block telephone impedance above 20 KHz.

2. Description of the Prior Art:

The prior art appears to be best exemplified in the following U.S. Letters Patent which were developed in a search directed to the subject matter in this application:

T,503 U

4,613,732	4,823,383
4,742,541	5,642,416
4,743,999	5,802,170

In U.S. Patent No. 4,823,383 issued to Cardot et al. on April 18, 1989, there is disclosed a protection device for terminal equipment on telephone subscriber premises which includes a voltage surge protection circuit and/or a filter for providing protection against radio frequencies and interference. The filter is comprised of series inductors **L1, L2, L3** and **L5** interconnected between terminals **E1** and **S1** and series inductors **L'1, L'2, L4** and **L'5** interconnected between terminals **E2** and **S2**. A capacitor **C5** is connected between the junctions of the inductors **L2, L3** and the inductors **L'2, L4**. The surge protection circuit includes thermistors **TH1, TH2** and voltage limiters **D1-D3**.

In U.S. Patent No. 5,802,170 issued to Smith et al. on September 1, 1998, there is disclosed a customer bridge module for connecting telephone company wiring and subscriber telephone wiring in a telephone network interface apparatus. In one embodiment, the customer bridge module includes overcurrent protection and an RFI filter. The overcurrent protection is formed by positive tempera-

ture coefficient resistors **220, 222** and inductors. The RFI filter is formed by inductors **224a-224c**, **226a-226c** and capacitors **236a-236c**. The inductors and capacitors are used to form a multi-pole low pass filter.

In U.S. Patent No. 5,642,416 issued to Hill et al. on June 24, 1997, there is disclosed an electromagnetic interference by-pass filter which suppresses RF noise currents conducted over the tip and ring leads of a telephone line-powered instrument. The filter includes first and second inductors **51, 53** and first and second capacitors **41, 43**.

It is generally well-known these days that many telephone subscribers or customers also have a personal computer located on their premises. At times, the computer user receives ADSL (an acronym for Asymmetric Digital Subscriber Line) signals from the Internet over the same telephone lines via an Internet Server Provider (ISP). In order to increase the speed of downloading of information from the Internet, an ADSL network interface is typically purchased and installed between the incoming telephone lines and the user's computer. However, since one or more telephone subscriber terminal equipment such

as telephone sets, facsimile machines and/or answering devices are also connected to the same incoming telephone lines via internal house wiring, ADSL interference problems may be caused by the terminal equipment which can significantly limit or reduce the data rate. In one situation, it has been experienced that the change of state from "on-hook" to "off-hook" of the telephone equipment and sometimes the telephone terminal equipment even being "on-hook" can create a resonance effect to occur so as to drop the impedance value to less than 10 Ω (Ohms) at a frequency as high as 500 KHz.

Accordingly, it would be desirable to provide an impedance blocking filter circuit for connection to the telephone terminal equipment causing the erratic input impedances. The impedance blocking filter circuit of the present invention is of a modular design so as to be easily connected by the subscriber in series with the offending telephone terminal equipment. The impedance blocking filter circuit blocks unconditionally any telephone impedances (e.g., open, short, capacitive, inductive, resonant, or any combination thereof) above the frequency of 20 KHz.

5

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide an impedance blocking filter circuit which effectively and efficiently eliminates ADSL interference caused by telephone terminal equipment.

It is an object of the present invention to provide an impedance blocking filter circuit for connection to telephone terminal equipment causing the erratic input impedances.

It is another object of the present invention to provide an impedance blocking filter circuit used in telecommunication systems for interconnecting between incoming telephone line and customer's terminal equipment so as to unconditionally block impedance above 20 KHz due to the customer's terminal equipment from an ADSL network interface unit and/or home networking interface unit.

It is still another object of the present invention to provide an impedance blocking filter circuit which is of a modular design so as to be easily connected in

series with the offending telephone terminal equipment by the subscriber.

It is still yet another object of the present invention to provide an impedance blocking filter circuit which is comprised of six inductors, two resistors, and a capacitor.

In accordance with a preferred embodiment of the present invention, there is provided an impedance blocking filter circuit used in telecommunication systems for interconnecting between incoming telephone lines and customer's terminal equipment so as to unconditionally block impedances above 20 KHz due to the customer's terminal equipment from an ADSL network interface unit and/or home networking interface unit. The filter circuit includes first, second and third inductors connected in series between a first input terminal and a first common point. The first inductor has its one end connected to the first input terminal and its other end connected to one end of the second inductor. The second inductor has its other end connected to one end of the third inductor. The third inductor has its other end connected to the first common point. A first resistor

has its one end also connected to the first common point and its other end connected to a first output terminal.

The filter circuit further includes fourth, fifth and sixth inductors connected in series between a second input terminal and a second common point. The fourth inductor has its one end connected to the second input terminal and its other end connected to one end of the fifth inductor. The fifth inductor has its other end connected to one end of the sixth inductor. The sixth inductor has its other end connected to the second common point. A second resistor has its one end also connected to the second common point and its other end connected to a second output terminal. A capacitor has its one end connected to the first common point and its other end connected to the second common point.

The foregoing applies specifically to the disclosure of the parent application Serial No. 09/195,522. A third embodiment of an impedance blocking filter circuit of the present invention added by way of this continuation-in-part application is quite similar to the schematic diagram of Figure 3, except that the filter circuit therein has been modified so that the resistors **R1** and **R2**

are replaced with first and second tank circuits **TC1** and **TC2**, respectively and a reed switch **K1** is connected in series with the capacitor **C1**. As a result, this third embodiment represents an improvement over the embodiment of Figure 3 since it overcomes the shunt additive capacitance problem and eliminates the deterioration in the return loss at the phone.

In addition, a fourth embodiment of an impedance blocking filter circuit of the present invention also added by way of this continuation-in-part application includes all of the components of the third embodiment and further has added successively seventh and eighth inductors **L7**,**L8**; a second capacitor **C2** and a second reed switch **K2** connected in series; and ninth and tenth inductors **L9**,**L10**. This produces a fifth-order filter circuit.

In a fifth embodiment, there is provided an impedance blocking filter circuit which is quite similar to the schematic circuit diagram of Figure 3, except that the filter circuit therein has been modified so to eliminate the resistors **R1** and **R2** and a reed switch **K1** is connected in series with the capacitor **C1**. The four

inductors **L1-L4** and the reed switch **K1** are all housed within a multi-sectioned wound bobbin inductor structure so as to significantly reduce the inductors' interwinding capacitance.

In a sixth embodiment, there is provided an impedance blocking filter circuit which includes all of the components of the fifth embodiment and further has added successively seventh and eighth inductors **L7,L8;** a second capacitor **C2** and a second reed switch **K2** connected in series; and ninth and tenth inductors **L9,L10.** The second reed switch **K2** is also housed within the multi-sectioned wound bobbin inductor structure. This produces a fifth-order filter circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention will become more fully apparent from the following detailed description when read in conjunction with the accompanying drawings with like reference numerals indicating corresponding parts throughout, wherein:

Figure 1 is an overall block diagram of a telecommunication system for interconnecting a central office and a subscriber's premises, employing an impedance blocking filter circuit of the present invention;

Figure 2 is an exploded, perspective view of one form of a module housing the impedance blocking filter circuit;

Figure 3 is a schematic circuit diagram of an impedance blocking filter circuit, constructed in accordance with the principles of the present invention;

Figure 4 is a schematic circuit diagram of a second embodiment of an impedance blocking filter circuit, in accordance with the principles of the present invention;

Figure 5 is a plot of input impedances of the impedance blocking filter circuit of Figure 3 for various telephone equipment impedances as a function of frequency;

Figure 6 is a schematic circuit diagram of current limiting protection circuitry for use with the filter circuit of Figure 3;

cl

Figure 7 is a schematic circuit diagram of a home network demarcation filter for use with the filter circuit of Figure 3;

Figure 8 is schematic circuit diagram of a third embodiment of an impedance blocking filter circuit in accordance with the present invention;

Figure 9 is schematic circuit diagram of a fourth embodiment of an impedance blocking filter circuit in accordance with the present invention;

Figure 10(a) is a top plan view of a dual winding inductor device housing one or two reed switches for use in the filter circuits of Figures 8 and 9;

Figure 10(b) is a side elevational view of the dual winding inductor device of Figure 10(a);

Figure 11(a) is a top plan view of a current sensor unit for housing a single inductor and a single reed switch for alternate use in the filter circuits of Figures 8 and 9;

Figure 11(b) is a side elevational view of the current sensor unit of Figure 11(a);

12

Figure 12 is a schematic circuit diagram of a fifth embodiment of an impedance blocking filter circuit utilizing a multi-sectioned bobbin structure;

Figure 13 is a schematic circuit diagram of a sixth embodiment of an impedance blocking filter circuit utilizing a multi-sectioned bobbin structure;

Figure 14(a) is a side view of a multi-sectioned bobbin structure for use in the filter circuits of Figures 12 and 13; and

Figure 14(b) is schematic diagram of the multi-sectioned bobbin structure of Figure 14(a).

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in detail to the drawings, there is illustrated in Figure 1 an overall block diagram of a telecommunication system **10** for interconnecting a telephone company's central office (CO) **12** and a subscriber's premises **14** over a transmission media such as a conventional twisted pair of telephone lines **16**. The telecommunication system **10** employs a plurality of impedance blocking filter circuits, constructed in accordance with

the principles of the present invention, in which each is contained in a modular housing **18**.

The central office **12** includes a telephone office switch **20** and an Internet Service Provider (ISP) **22**. The telephone office switch **20** is used to send voice signals via a low-pass filter **24** and a surge protector **26** to the telephone line **16**. The ISP **22** transmits ADSL data signals to a modem **28** which are then sent to the telephone lines **16** via a high-pass filter **30** and the surge protector **26**. It should be understood that the voice signals from the telephone office switch **20** and the ADSL data signals from the ISP **22** can be transmitted simultaneously to the telephone lines **16**. Further, the voice signals (speech) are in the frequency band between 300 and 3400 Hz, and the ADSL data signals are in the frequency band between 20 KHz and 1.1 MHz .

The subscriber's premises **14** includes a Network Interface Device (NID)/surge protector unit **32** which is connected to the incoming telephone lines **16** on its input side and is connected to the subscriber's internal wiring or house wiring **34** on its output side via a demarcation RJ-11 jack and plug unit **36**. As can be seen, the

subscriber's premises further includes a number of terminal equipment such as a plurality of telephone sets **40**. At times, the computer user will be downloading information to a personal computer **38** from the Internet by receiving ADSL data signals transmitted by the ISP **22**.

In order to optimize the downloading of this information from the Internet, the user can purchase and install an ADSL network interface unit **42** for connection between the computer **38** and a RJ-11 jack and plug unit **44**. The ADSL network interface unit **42** includes a high-pass filter **41** connected to the RJ-11 unit **44** and an internal modem **43** connected to the computer **38**. The RJ-11 unit **44** is connected to the house wiring **34** for receiving the ADSL signals from the telephone lines **16**. However, it will be observed that the plurality of telephone sets **40** are also connected to the same house wiring **34** via RJ-11 units **46, 48** and **50**, respectively.

If it were not for the impedance blocking filter circuits **18** in the present invention, the output impedance from each of the telephone sets **40** would be connected in parallel with the input impedance of the ADSL unit **42**. Since the output impedances from the tele-

phone sets are subject to wide variations due to, for example, changing from "on-hook" to "off-hook" so as to present either an open, a short, capacitive, inductive, resonant, or any combination thereof at frequencies above 20 KHz, this erratic impedance can significantly affect the rate of the ADSL data signals being received by the computer **38** via the ADSL network interface unit **42**.

Therefore, the main purpose of the impedance blocking filter circuit of the present invention is to isolate the terminal equipment (telephone sets) impedances from the ADSL unit **42** and the house wiring **34** so as to eliminate degradation of the performance of the ADSL unit **42**. Further, the impedance blocking filter circuit serves to attenuate the ADSL data signal from being received by the telephone sets **40** in order to prevent non-linear conversion to voice band signals. Moreover, to facilitate the installation required by the customer, the filter circuit is contained in the modular housing **18**.

As can best be seen from Figure 2, one form of the modular housing **18** includes a base **52** and a snap-on removable cover **54**. The base has a printed circuit board **56** which is fixedly secured thereto by screws **58** and has

mounted thereon the electrical circuit components for the filter circuit **59**. One end of the modular housing **18** has a RJ-11 jack **60** formed integrally therewith for connection to the telephone set. This connection is achieved by plugging a RJ-11 plug (not shown) from a telephone set into the jack **60**. The other end of the modular housing **18** has a short length of cable **62** extending therefrom and terminating in a RJ-11 plug **64** which is connectable to the house wiring. In particular, the plug **64** is connected to the house wiring **34** by plugging the same into a wall socket (not shown) having a RJ-11 jack.

In Figure 3, there is shown a detailed schematic circuit diagram of the impedance blocking filter circuit **59** of the present invention for connection in series between the house wiring **34** and the terminal equipment (telephone set) of Figure 1. The filter circuit **59** includes two input (tip and ring) terminals **66, 68** which are connectable to the house wiring **34** via the RJ-11 plug **64** and two output (tip and ring) terminals **70, 72** which are connectable to the telephone set **40** via the RJ-11 jack **60**. The filter circuit **59** is comprised of inductors **L1-L6**, a capacitor **C1**, and resistors **R1, R2**.

The inductors **L5, L3, L1** and the resistor **R1** are connected in series between the first or tip input terminal **66** and the first or tip output terminal **70**. Similarly, the inductors **L6, L4, L2** and the resistor **R2** are connected in series between the second or ring input terminal **68** and the second or ring output terminal **72**. The inductors **L5** and **L6** are each preferably formed of a ferrite toroid. The inductors **L3** and **L4** have the same inductance values, and the inductors **L1** and **L2** have the same inductance values. The inductor **L1** and the first resistor **R1** are connected together at a common point **A** and to one side of the capacitor **C1**. The inductor **L2** and the second resistor **R2** are connected together at a common point **B** and to the other side of the capacitor **C1**. The resistors **R1** and **R2** also have the same values.

As previously pointed out, the primary purpose of the impedance blocking filter circuit **59** is to block the impedances from the telephone set at above the frequency of 20 KHz from reaching the house wiring **34**, thereby preventing adverse performance of the ADSL network unit **42** (Figure 1). In particular, the ADSL data signals being in the frequency range of 20 KHz and 1.1 MHz are mainly blocked by the inductors **L1** and **L2**. However, it has been experienced that some telephone sets have an

input capacitance of less than 5 nf which can cause resonant impedances to occur within the ADSL band. In order to eliminate this undesirable effect, the capacitor **C1** is used to lower any resonance into an acceptable dead band at around the 10 KHz frequency. Further, the capacitor **C1** also provides additional attenuation of the ADSL signals so as to prevent driving the telephone impedance into a non-linear region and converting the high frequency ADSL signals into audible signals which can be heard by the subscriber or converted to another ADSL band and cause ADSL interference. While there may still exist other minor resonances in the telephone set in the frequency range of between 20 KHz and 60 KHz, their undesirable effect is significantly reduced by the resistors **R1** and **R2** which produce a de-Q effect. It should be noted that the inductors **L1** and **L2** are formed as separate inductors so as to avoid longitudinal impedance problems as well as blocking differential impedances.

Since the inductors **L1** and **L2** have their own frequency limitations (e.g., self-resonant frequency), the inductors **L3** and **L4** are provided so as to block the telephone impedances in the frequency band of 1 MHz to 20 MHz. These inductors **L3, L4** are necessary when

phoneline home networking interface units (Figure 1) are being used in conjunction with the ADSL network interface unit **42**, as will be explained hereinafter. The inductors **L5** and **L6** are provided so as to block the telephone set impedances in the frequency band of 20 MHz to 500 MHz, which will prevent any problems caused by TV/FM interference.

For completeness in the disclosure of the above-described filter circuit but not for purposes of limitation, the following representative values and component identifications are submitted. These values and components were employed in a filter circuit that was constructed and tested, and which provides high quality performance.

T 1,020

PART	TYPE or VALUE
L1, L2	10 mH
L3, L4	220 μH
L5, L6	ferrite toroid, 75 μH
C1	22 nf
R1, R2	22 Ω

With these above values being used, the input impedance of the impedance blocking filter circuit **59** was plotted for various telephone equipment impedances (e.g., open, short, capacitive, inductive, resonant, or a combination of these conditions) as a function of frequency and is illustrated in Figure 5. As can be seen from the various curves, the input impedance across the input terminals **66**, **68** of the impedance blocking filter circuit **59** for any telephone impedances connected across its output terminals **70, 72** is equal to or greater than 2K Ohms at frequencies above 40 KHz.

The impedance blocking filter circuit **59** of Figure 3 is basically a second-order filter and has been found to minimize adequately voice band transmission effects when up to eight (8) filter circuits are installed into the telecommunication system of Figure 1. In order to provide higher attenuation at frequencies above 20 KHz, there is shown in Figure 4 a schematic circuit diagram of a second embodiment of a third-order impedance blocking filter circuit **59a** of the present invention. The third-order filter circuit of Figure 4 is substantially identical to the second-order filter circuit of Figure 3, except there has been added an inductor **L7** and an inductor **L8**. The inductor **L7** is interconnected between

the common point **A** and the first resistor **R1**, and the inductor **L8** is connected between the common point **B** and the second resistor **R2**. The inductors **L7** and **L8** have the same inductance values.

Based upon tests conducted on the third-order filter circuit of Figure 4, it was observed that higher attenuation was provided at frequencies above 20 KHz. However, it was found that the number of such third-order filter circuits which could be connected to the telecommunication system of Figure 1 was limited to three or four. This is due to the fact that the inductor values of **L1, L2, L7** and **L8** of Figure 4 are smaller (on the order of 5-10 mH) than the ones in Figure 3, the capacitor value of **C1** of Figure 4 is larger (on the order of 33-47 nf) than the one in Figure 3, and the additive capacitive loading caused by each added filter circuit will adversely affect the voice band performance. Thus, the optimized operation between voice performance and ADSL performance was found to exist when only three or four filter circuits **59a** were installed.

While the filter circuit of Figure 3 performed adequately, the inventor has found based upon further test-

ing that a transient problem will occur when the telephone set goes "off-hook" at the peak of the ring signal. This "off-hook" transient condition may cause current spikes to occur which are higher than 600 mA. As a result, the high current will tend to saturate the inductors, thereby momentarily lowering the input impedance of the filter circuit and thus adversely affects the data on the ADSL signal being transmitted to the interface unit **42**.

In order to overcome this current transient problem, the inventors have developed fast current limiting protection circuitry **74** for providing protection against the "off-hook" transients. In Figure 6 of the drawings, there is shown a schematic circuit diagram of the current limiting protection circuitry **74** which is comprised of depletion mode N-channel field-effect transistors (FET) **Q1, Q2**; resistors **R1a, R2a**; and varistors **RV1, RV2**. The FET **Q1** has its drain electrode connected to a first input terminal **76**, its source electrode connected to one end of the resistor **R1a**, and its gate electrode connected to the other end of the resistor **R1a**. The common point **C** of the gate electrode of the transistor **Q1** and the resistor **R1a** is also joined to the first output terminal **78**. Similarly, the FET **Q2** has its drain connected to a second

input terminal **80**, its source connected to one end of the resistor **R2a**, and its gate electrode connected to the other end of the resistor **R2a**. The common point **D** of the gate of the transistor **Q2** and the resistor **R2a** is also joined to a second output terminal **82**. One end of the varistor **RV1** is connected to the drain of the transistor **Q1**, and the other end thereof is connected to the common point **C**. One end of the varistor **RV2** is connected to the drain of the transistor **Q2**, and the other end thereof is connected to the common point **D**.

In use, the current limiting protection circuitry **74** replaces the resistors **R1** and **R2** of Figure 3. The first and second input terminals **76, 80** of the protection circuitry **74** are connectable to the common points **A** and **B** of Figure 3, and the first and second output terminals **78, 82** thereof are connected to the tip and ring output terminals **70, 72** of Figure 3. The transistors **Q1, Q2** may be similar to the ones commercially available from Supertex Corporation under their Part No. DN2530N3. The varistors may be similar to the type ZNR which are manufactured and sold by Panasonic Corporation. The resistors **R1a** and **R2a** have the same resistance value and are on the order of 5-20 Ohms depending on the thresholds of the transistors **Q1, Q2**. It should be understood that

the transistors **Q1, Q2** have a large tolerance on current limit and the resistors **R1a, R2a** permit the desired current limit value to be adjusted. Alternatively, the resistors **R1a, R2a** may have a value of zero Ohms or be entirely eliminated.

In normal on-hook operation, the transistors **Q1** and **Q2** are rendered conductive and have an on-resistance value of about 10 Ohms. When the telephone set goes "off-hook" into high ringing voltage, the gate-to-source voltage of the forward conducting FET will become more negative due to the resistors **R1a, R2a**. As a result, the resistance of the transistors **Q1, Q2** will go very high which will limit the current spikes to approximately 70-100 mA. The transistor **Q1** serves to limit the current flowing in a first direction, and the transistor **Q2** serves to limit the current flow in a reverse direction. Further, the varistors **RV1, RV2** defining transient protection means function to clamp transients caused by lightning and power shorts from damaging or destroying the FETs **Q1, Q2**.

In view of continuing increased use of home computers and the high demand for accessing of

information from the Internet in the last decade or so, many of the subscribers will be multi-PC homes. As shown in Figure 1, the subscriber's premises or small business will typically have a second computer **38a** also connected to the same internal house wiring **34**. In order to effect high-speed data transfer in the multi-PC environment, there will be required phoneline home networking interface units **42a** for using the internal house wiring in the frequency band above 5 MHz so as to interconnect the multiple computers **38**, **38a** or other devices at data rates above 10 MB/s as illustrated. While the impedance filter circuit of the present invention adequately filters and blocks the telephone impedances from the home networking signals, which are in the frequency band of 5-10 MHz, it will be noted that the home networking signals from the telephone company's C.O. are however still connected to the house wiring via the NID/surge protector unit **32**.

In order to solve this problem, the inventor has developed a home network demarcation filter **84** as shown in dotted lines in Figure 1 for connection at a point of demarcation (NID/surge protector unit **32**) between the telephone company's incoming lines **16** and the subscriber's internal house wiring **34** via the demarcation

unit **36**. A schematic circuit diagram of the home network demarcation network is depicted in Figure 7. The demarcation filter **84** includes two input (tip and ring) terminals **86, 88** which are connectable to the incoming lines via the jack side of the demarcation unit **36** in the NID/surge protector unit **32** and two output (tip and ring) terminals **90, 92** which are connectable to the internal house wiring via the plug side of the demarcation unit **36**. The demarcation filter is comprised of six inductors **L9-L14** and two capacitors **C2, C3**. In use, the demarcation filter is transparent to the ADSL data signals having the frequencies between 20 KHz and 1.1 MHz but will produce an attenuation of more than 40 dB for frequencies above 5.5 MHz. The demarcation filter will also provide an inductive input impedance for above 5 MHz frequency band so as to prevent loading down the home networking signals on the incoming phone lines and also adds data security benefits.

From the foregoing detailed description, it can thus be seen that the present invention provides an impedance blocking filter circuit used in telecommunication systems for interconnecting between incoming telephone lines and customer's terminal equipment so as to unconditionally block impedances above 20 KHz due to the customer's

terminal equipment from an ADSL network interface unit and/or home networking interface unit. The impedance blocking filter circuit is comprised of six inductors, two resistors, and a capacitor.

While the second-order impedance blocking filter **59** of Figure 3 and the third-order impedance blocking filter **59a** of Figure 4 both perform adequately for unconditionally blocking telephone impedances above 20 KHz, the inventor has found that based upon additional testing they suffer from the disadvantages of causing (1) a shunt additive capacitance problem and (2) a deterioration in the return loss at a phone set, when the number of such filter circuits are added increasingly in parallel into the telecommunication system of Figure 1.

The shunt capacitance problem is caused by the added capacitance from all of the filter circuits connected to the on-hook phones. The return loss problem is due to the fact that the series inductances of the impedance blocking filter circuit connected to the telephone set going "off-hook" will cause a resonance to occur in the frequency range of 2-5 KHz with the total capacitance seen, which is equal to the sum of the line capacitance plus the capacitance from the filter circuits. Further,

as the total capacitance is increased this will also cause a lower resonant frequency which will create a phase shift so to unbalance the telephone hybrid. As a result, the side tone level of the "off-hook" telephone set is caused to increase.

In order to overcome this problem, there is provided in Figure 8 a third embodiment of a second-order impedance blocking filter circuit **59b** of the present invention. The third embodiment includes all of the circuit elements used in the filter circuit of Figure 3, except for the resistors **R1** and **R2**, and further includes a reed switch **K1** and a return loss correction circuit consisting of a first tank circuit **TC1** and a second tank circuit **TC2**.

In particular, the reed switch **K1** connected in series with the capacitor **C1** is connected between the common points A and B. Further, the first tank circuit **TC1** is comprised of a first winding inductor **W1**, a capacitor **C3**, and a resistor **R3** all connected together in parallel and between the common point A and the output tip terminal **70**. Similarly, the second tank circuit **TC2** is comprised of a second winding inductor **W2**, a capacitor **C4**, and a resistor **R4** all connected together in parallel

and between the common point B and the output ring terminal **72**. In addition, there provided optionally a metal-oxide varistor **D1** connected in series with the capacitor **C1** and in parallel with the reed switch **K1**. The varistor **D1** serves to protect the reed switch **K1** from being damaged by transients when the telephone set is in the on-hook condition.

In use, when a telephone set goes "off-hook" DC loop current will flow which creates a DC magnetic field in the first and second winding inductors **W1,W2**. This will cause only the reed switch **K1** of the filter circuit **59b** connected to the "off-hook" telephone set to become actuated or closed by the DC magnetic field. As a consequence, the shunt additive capacitances from all of the filter circuits connected to the "on-hook" phones have been eliminated.

Moreover,the first winding inductor **W1** and the capacitor **C3** of the first tank circuit **TC1** will cause a resonance to occur at the frequency of about 2 KHz. The impedance of the first tank circuit **TC1** above the resonant frequency will appear as a capacitive reactance, which will substantially cancel the inductive reactance

of the filter circuit **59b**. The resistor **R3** sets the Q or the slope of the resonance so as to best match the effects of the inductive impedance of the filter circuit. In this manner, the return loss at the "off-hook" phone set is significantly improved, thereby reducing the side tone level of the telephone set. Similarly, the second winding inductor **W2**, the capacitor **C4**, and the resistor **R4** of the second tank circuit **TC2** operate in an identical manner to first winding inductor **W1**, the capacitor **C3**, and the resistor **R3** of the first tank circuit **TC1**.

In Figure 9, there is illustrated a fourth embodiment of an impedance blocking filter circuit **59c** of the present invention. The fourth embodiment includes all of the circuit components of the filter circuit **59c** of Figure 8 and has added an inductor **L7** and an inductor **L8**. The inductor **L7** is interconnected between the common point A and the first tank circuit **TC1**, and the inductor **L8** is interconnected between the common point B and the second tank circuit **TC2**. The filter circuit **59c** as described thus far is essentially a third-order filter circuit which provides a better stop band performance than the second-order filter circuit **59b** of Figure 8.

Referring still to Figure 9, a second reed switch **K2** and a capacitor **C2** have been successively added to convert the third-order filter circuit to a fourth-order filter circuit which is optimized for better operation for full rate ADSL modems. In particular, the reed switch **K2** connected in series with the capacitor **C2** is joined between common points C and D. In addition, there is provided optionally a metal-oxide varistor **D2** connected in series with the capacitor **C2** and in parallel with the reed switch **K2**. Likewise, the varistor **D2** is used to protect the reed switch **K2** from being destroyed by transients when the telephone set is in the on-hook condition.

Further, an inductor **L9** and an inductor **L10** are added successively so as to produce a fifth-order filter circuit. Specifically, the inductor **L9** is interconnected between the inductor **L7** at the common point C and the first tank circuit **TC1**. The inductor **L10** is interconnected between the inductor **L8** at the common point D and the second tank circuit **TC2**.

In addition, a thermo-fuse **F1** may be optionally connected in series the inductors **L5**, **L3**, **L1**, **L7**, **L9** and

32

the tank circuit **TC1** which are arranged between the input tip terminal **66** and the output tip terminal **70**. For example, the thermo-fuse **F1** may be electrically interconnected between the input tip terminal **66** and the inductor **L5**. Typically, the thermo-fuse **F1** is located physically adjacent to one of the inductors or the resistor in order to sense the highest temperature within the filter circuit. The fuse **F1** provides a safety feature and will open when the sensed temperature of the filter circuit exceed a specified trip temperature. The fuse functions as a safety protection means for preventing the filter circuit from overheating and causing a fire due to a power cross on the phone lines.

In Figure 10(a), there is shown a top plan view of a dual winding inductor device **T1** for use in the filter circuits of Figures 8 and 9. Figure 10(b) is a side elevational view of the dual winding inductor device. As can be seen, inductor device **T1** includes a cylindrical-shaped housing **110** which contains the first winding inductor **W1** of the first tank circuit **TC1**, the second winding inductor **W2** of the second tank circuit **TC2**, the reed switch **K1**, and the reed switch **K2**.

In Figure 11(a), there is depicted a top plan view of an alternate current sensor unit **CS** for use in the filter circuits of Figures 8 and 9. Figure 11(b) is a side elevational view of the current sensor unit **CS**. The current sensor unit **CS** is formed of cylindrical housing **112** and contains a single inductor **L** and a single reed switch **K**. It should be apparent to those skilled in the art that the dual winding inductor device **T1** can be replaced with two such current sensor units **CS** so as to render the same operation. Since the windings **W1**,**W2** or the inductor **L** is used to drive the reed switches **K1**,**K2** (K), the reed switch is selected to be actuatable on a loop current threshold of approximately 14-20 mA. If the loop current threshold is below 14 mA, the reed switch may chatter during ringing on a 1 REN telephone and may thus shorten the useful life of the reed switch. On the other hand, if the loop current threshold is above 20 mA, then the amount of loop current may be insufficient to be actuable in the worst case condition (e.g., the longest cable).

In Figure 12, there is illustrated a fifth embodiment of an impedance blocking filter circuit **59d** of the present invention. the fifth embodiment is substantially identical to the first embodiment of the

second-order filter circuit of Figure 3, except that the resistors **R1** and **R2** have been eliminated and a reed switch **K1** has been added in series with the capacitor **C1** located between the common points A and B. Further, the four single inductors **L1, L2** and **L3, L4** of Figure 3 have replace by a multi-sectioned wound bobbin inductor structure **T2**. It will be noted that the bobbin structure **T2** includes a tip winding **TW** (corresponding to replace inductors **L1,L3**) connected between the inductor **L5** and the common point A , and a ring winding **RW** (corresponding to replace inductors **L2,L4**) connected between the inductor **L6** and the common point B. Further, the bobbin structure **T2** houses the reed switches **K1,K2**. The tip(ring) winding **TW**(**RW**) combines the inductor **L1**(**L2**) for the ADSL frequency band (20KHz to 1.1MHz) and the inductor **L3**(**L4**) for the mid-frequency band (1MHz to 20MHz) into a single coil. It has been found that the filter circuit **59d** is more economical to manufacture and assemble, but yet eliminates the shunt additive capacitance problem of the filter circuits connected the "on-hook" phone sets. Optionally, a return loss correction circuit consisting of a first tank circuit **TC1** and a second tank circuit **TC2** may be interconnected between the common points A,B and the output terminals **70,72**.

In Figure 13, there is shown a sixth embodiment of an impedance filter circuit **59e** of the present invention. the sixth embodiment includes all of the circuit components of the filter circuit **59d** of Figure 12 and has added an inductor **L7** and an inductor **L8**. The inductor **L7** is interconnected between the common point A and the output tip terminal **70**, and the inductor **L8** is interconnected between the common point B and the output ring terminal **72**. The filter circuit thus far described is essentially a third-order filter circuit for producing a better stop band.

Referring still to Figure 13, a second reed switch **K2** and a second capacitor **C2** have been further added so as to convert the third-order filter circuit to a fourth-order filter circuit which is optimized for better operation for full rate ADSL modems. In particular, the second reed switch **K2** connected in series with the second capacitor **C2** are joined between nodes **C** and **D**. It will be noted that the second reed switch **K2** is also incorporated into the bobbin structure **T2**. Further, an inductor **L9** is added between the inductor **L7** and the node **E**, and an inductor **L10** is added between the inductor **L8** and the node **F** in order to convert the fourth-order filter circuit to a fifth-order filter circuit. Optionally, a

thermo-fuse **F2** may be connected in a manner similar to the one in Figure 9.

In Figure 14(a), there is shown a side view of a wiring bobbin structure **T2** having multiple sections **S1-S6** for use in the circuits of Figures 12 and 13. Figure 14(b) is schematic diagram of the bobbin structure **T2** of Figure 14(a). The bobbin structure includes a first narrow section **S1** on which is wound the inductor **L3**, first wider sections **S2,S3** on which are wound the inductor **L1**, a second narrow section **S4** on which is wound the inductor **L4**, and second wider sections **S5,S6** on which are wound the inductor **L2**. The inductors **L1,L3** are combined on the same coil and is represented by the tip winding **TW** in Figure 14(b). Similarly, the inductors **L2,L4** are combined on the coil and is represented by the ring winding **RW**.

The inventor has designed purposely the bobbin structure **T2** to include the narrow section **S1**(**S4**) on which is wound the higher frequency of the coil (e.g., inductor **L3,L4**) since there will be less winding capacitance so as to obtain a maximum useful frequency range. Further, by dividing the bobbin structure into a

plurality of sections the beginning of the tip(ring) winding **TW**(**RW**) on pin 1 (pin 5) will be farther removed from the end of the tip (ring) winding on pin 4 (pin 8). As result, the interwinding capacitance will be reduced, thereby increasing the useful frequency range of the coil. The first reed switch **K1** with pins 2 and 7 is disposed within the center of the bobbin structure **T2** so as to be actuable by the windings **TW, RW**. Further, the second reed switch **K2** with pins 3 and 6 may also be formed with the center of the bobbin structure and actuated by the same winding **TW, RW**.

While there has been illustrated and described what is at present considered to be a preferred embodiment of the present invention, it will be understood by those skilled in the art that various changes and modifications may be made, and equivalents may be substituted for elements thereof without departing from the true scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the central scope thereof. Therefore, it is intended that this invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out the invention, but that the invention will include

all embodiments falling within the scope of the appended claims.